POPULATION DYNAMICS OF COPEPODA AND CLADOCERA IN AN IOWA FARM POND, SUMMER 1973

An abstract of a Thesis by
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The problem. To calculate rates for birth, death, and natural increase of zooplankton found in an unpolluted artificial pond. This will serve as a basis for comparisons with other bodies of water to show man's effect upon one of the most basic of all ecosystems.

Procedure. Water samples were collected with a Kemmerer Water Sampler and poured into a plankton net for concentrating the organisms. They were killed in 4% formalin and counted keeping records of species numbers, sex, and reproductive condition. Abiotic factors were also measured and recorded.

Findings. The greatest concentration of organisms was always located at the 2.5 meter depth. Species' densities did fluctuate directly with primary productivity after a certain lag period, but no other factor was found to have an influence upon the zooplankton location or density.

Conclusion. All of the populations varied greatly, but food had the greatest direct effect upon the densities.

Recommendations. It would be necessary to conduct a long term study of the same pond so that a complete understanding could be obtained of development, growth, and extinction of the various populations. For a complete understanding of the zooplankton community, techniques involving evaluations of competition, predation and interreactions between populations should be developed and included.

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Roger L. Welchlin

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INTRODUCTION

One of the problems facing mankind today is the effect of water pollutants and eutrophication on populations of aquatic organisms. Zooplankton production in a body of water is of concern, because it represents the energy link between algae and fish producing food for man. In order to determine relationships and how they vary in a polluted situation more information must be gained about unpolluted habitats and their populations. Only then can we determine how quality and quantity of production is influenced by man and his activities.

Early workers have attempted to explain the observed variation in populations by some simple environmental feature such as temperature or light. Most recent investigators have realized that the plankton community is influenced qualitatively and quantitatively by an entire complex of environmental factors (Davis, 1966; Hazelwood and Parker, 1961).

The study of a natural population in its environment requires a careful evaluation of the interrelationships between the population and the biological, chemical, and physical factors of the environment. Cladocerans along with copepods provide ideal populations for study since they are found in almost any body of water during the spring, summer, and fall. These organisms are subjected to extreme fluctuations in density, the causes of which are not adequately understood (Hazelwood and Parker, 1961).

Many cladocerans quickly populate a lake or pond in the spring or summer, but later are almost completely eliminated as more slowly developing cladocerans and copepoda species increase. These cladocerans convert environmental energy into individuals by rapid parthenogenic reproduction. Copepods do not develop population increases as rapidly and the oscillations are dampened. The storage of lipids enables the copepods to take advantage of phytoplankton pulses by converting abundant environmental energy to stored energy. The contrasting methods of utilizing environmental energy makes it possible to have overlapping niches (Armitage and Davis, 1967). Since cladocera seem to be opportunistic, species that respond quickly to changes in their environment, the survival of the group may depend on the abilities of various species to produce large populations during optimal periods (Tash and Armitage, 1967).

Davis (1966) felt that the environmental factors responsible for population fluctuations are of three groups: (1) physical factors; temperature, light penetration, horizontal and vertical mixing of water, etc., (2) chemical factors: oxygen, carbon dioxide, hydrogen sulfide, alkalinity, phosphate, nitrates, etc., and (3) biotic factors: competition, predation, densities, etc.

The effect of temperature on various life stages, speed of reproduction, and mortality have been observed by Kibby (1971); Stross and Kangas (1969); Hutchinson (1967); Elbourn,

(1966) and Hall (1964). B.O.D. was found by Lieberman (1970) to be more restrictive than a preference to levels of dissolved oxygen by certain cladocerans. Hall (1964) indicated that levels of alkalinity, dissolved gases and light, either tend to remain relatively constant in the zone of the lake inhibitated by Daphnia or seem to be of little importance. O'Brien (1972) felt that the population drop of Ceriodaphnia reticulata was due to a decrease of the pH in the water.

Cowell (1967) found that densities of Diaptomus, Cyclops, and Daphnia generally increased with depth and the maximum concentration occurred near the bottom; however, Bosmina showed an inverse relationship to depth. Parr (1967) found that Daphnia pulex had a rather strong negative phototaxis; while Ceriodaphnia reticulata preferred the cooler hypolimnion and was more light tolerant.

Food, according to Hall, Cooper, and Werner (1970) is the most likely factor. Nearly all herbivorous zooplankters feed on a rather narrow range of the available particle size and nutrient levels appear to strongly influence zooplankton production (Burns, 1969, 1968; Burns and Rigler, 1967).

Ingle, Wood, and Banta (1937) found that semi-starved Daphnia live about 40% longer which would greatly extend the species reproductive potential when abundant food was again found. Population size does not appear to be solely determined by food; predation pressure can produce population minimums (Dodson, 1973). Population density was found by Frank, Boll and Kelly (1957) to have an effect upon reproduction rates.

The lag effects of various environmental factors upon populations have been studied in depth (Armitage, Saxena, and Angino, 1973; Hazelwood and Parker, 1963). Densities of cladocera were correlated with the concentrations of oxygen, bicarbonate, and carbonate ions. These three chemical factors are regarded as indexes of photosynthetic activity which is in turn considered to be a measure of the amount of food available for cladocera. On the basis of these findings it was concluded that in the environment provided by the habitat, densities of cladocera are primarily determined by food supply and show a significant correlation with chemical and physical factors related to food supply (Borecky, 1956). More frequently, some complex combination of environmental influences determine the quality and quantity of plankton (Davis, 1966).

Ryther (1954) found that certain fresh-water phytoplankton inhibit some zooplankton by the production of external metabolites. Culturally enriched ponds are characterized by algae blooms leading to decreased zooplankton numbers.

Various community relationships have been identified by work in the field as well as in the laboratory. Pennak (1957) studied the relationships of various populations of cladocerans and copepods in Colorado ponds. When present, vertebrates are more effective predators than are invertebrates. Depending upon size, age, and species of fish and amphibians, microcrustaceans will be preyed upon at various rates (Wong and Ward, 1972; King, 1964). Goulden (1971) believed that the predaceous midge larvae were responsible for causing population minimums rather than the absence of food. The ability of cladocerans to overcome this pressure is greatly aided by their ability to reproduce parthenogenetically. Confer (1971) suggested that zooplankton predation can greatly affect herbivorous cladoceran numbers as he observed *Mesocyclops edax* predation upon *Diaptomus floridanus*. This feeding rate of *M. edax* is believed to be density dependent. Most herbivorous cladocerans are larger than most fresh-water copepods; consequently selective predation by cyclopoid copepods on smaller calanoid copepods is high. McQueen (1969) found that adult *Cyclops bicuspidatus thomasi* ate 31% of its own nauplis standing crop as well as 30% of the calanoid nauplis standing crop during midsummer when about 85% of *C. b. thomasi* copeipid stage IV encysted at the bottom. Maly (1970) suggested that predators can alter the adult sex ratio in prey species if there is sexual dimorphism or behavioral differences between the two sexes. Wright (1965) found the ecological efficiency of most zooplankton to be about 10%.

Experimental manipulation in intra and inter-species competition, using ^{14}C labeled algae, bacteria, and detritus revealed clear competitive effects only with algae when using two cladocerans (Allan, 1973). Slobodkin (1954) found that it is extremely unlikely that *Daphnia* in nature ever existed in a state of perfect equilibrium except under a rare condition of age and size frequency distribution. Keen (1973) observed chydorid populations and found that by monitoring the littoral temperatures one could determine developmental times of eggs over a range of temperatures. Most of the chydorid population losses appear to be predatory while emigration and natural mortality were not important. Synchronous reproduction can cause great fluctuations, but clumped age distribution of eggs must accompany this; and there is little evidence for this.

Copepods and cladocerans have been of interest to several researchers in the midwest. Seasonal distributions were observed by Armitage (1961) in northeastern Kansas. Armitage and Davis (1967) studied population structure of some pond microcrustacean communities in which they found an almost identical population grouping to that described by Pennak (1957) which included one cyclopoid, one calanoid copepod and three cladocerans. Armitage et al. (1973) and Angino, Armitage, and Saxina (1973) observed population dynamics of *Diaptomus pallidus* and *Daphnia ambigua* respectively and their reaction to 27 environmental variables with reference to a time lag.

McGrath (1973) and Asch (1971) studied copepoda and cladocera and their spatial distribution in Red Rock Reservoir, Iowa. Asch (1971) also found that there was no significant difference in avoidance reaction of zooplankton between the Van Dorn Water Sampler and the Kemmerer Water Sampler. Bulkley and Scheider (1970) working in Clear Lake, Iowa, found that superdispersion or patchiness in abundance is common in zooplankton distributions.

When the early researchers followed the rise and fall of zooplankton species either in natural environments or in the laboratory, only the densities were of interest. In order to determine what that particular species was doing, it was necessary to understand the birth rate (b'), death rate (d'), and the rate of natural increase (r'). Edmonson's work (1968) is referred to most frequently when mathematical calculations are involved. Again some researchers worked with these population determiners in the laboratory or in a closely controlled artificial pond. Dodson (1973) worked with mortality rate of <u>Daphnia rosea</u> and Geiling and Campbell (1972) worked with the developmental and reproductive rate of <u>Diaptomus pallidus</u>. Hazelwood and Parker (1961) worked out the population dynamics of <u>Daphnia schodleri</u> and <u>Diaptomus leptomus</u> while Slobodkin (1954) worked out the dynamics of <u>Daphnia obtusa</u>.

Other researchers attempted to gain dynamic information through field studies. Even though the data was harder to collect and the margin of error was large, such field studies do attempt to show as accurately as possible the true nature of a natural population. George and Edwards (1974) calculated b', d', and r' for *Daphnia hyalina* while *Diaptomus clavipes* yielded its information to Gehrs (1974). Armitage et al. (1973) and Angino et al. (1973) produced reproductive information about *Diaptomus pallidus* and *Daphnia ambigua* respectfully. *Cerodaphnia reticulata* was studied by Hall et al. (1970). Chydoridae populations were studied by Keen (1973) and Hall (1964) worked out some vital statistics as related to food supply for *Daphnia galeata mendotae*.

Laboratory investigations are often powerful and yield knowledge of the fundamental population growth but are limited to specific conditions seldom found in nature. In field studies, analysis are limited to correlation of population fluctuations with environmental variables and frequently involves large errors in estimates of the inferred rates (Hall, 1964). The survival of the group may depend on the abilities of various species to produce large populations during optimal periods. The production of large populations provides the chance for larger numbers of individuals to produce ephippia that over-winter to carry the species into the next year. A cladoceran ephippium typically contains one or two eggs; while a single copepod may produce as many as 120 over-wintering eggs. Thus cladocera populations must be four to thirty times larger in order to produce the same number of diapause eggs (Tash and Armitage, 1967).

The limnologists have found enough work to keep themselves busy for several lifetimes; but if they are to understand the lakes, ponds, and rivers and their biology as the main basis of the food web, this type of research must continue.

In an aquatic habitat such as a small farm pond with an unfertilized, little grazed alfalfa-hay watershed, the influence of man should be minimal. Then cladocera and copepod populations can be studied and their fluctuations can be followed and identified with natural environmental factors. The population dynamics can be determined and an attempt to isolate controlling mechanisms on microcrustacean populations thereby should be simplified.

METHODS AND MATERIALS

From June 14 to July 30, 1973 qualitative and quantitative collections of microcrustaceans and water samples for physiochemical analysis were taken from a small farm pond. On 14 dates between 10 AM and noon four liters of water were collected from four depths from three separate stations.

The pond is located 21 km southwest of Des Moines in Warren County, Iowa, Linn Township, NE¼ of NE¼ of Section 29, in Township 77 and Range 23. The pond was constructed in 1967 by an earthen impoundment of approximately 100 m long and 7 m high. The surface runoff of 40 acres (16 ha) maintains an almost rectangular pond at 1.5 acres (0,68 ha) with a maximum depth of 4.0 m (Figure 1).

Quantitative zooplankton samples were obtained at the three stations on a transect located through the deep part of the pond. At each station four samples were taken at one meter intervals with the first sample taken at 0.5 m. For one sample, four liters of water were collected with a two-liter plexiglass Kemmerer Water Sampler and concentrated by pouring the contents into a #20 conical plankton net with attached 30 ml screw top vial. The net was lowered into the water three times to a point where water would not come over the lip of the net but would wash organisms from the sides of the net into the vial (McGrath, 1973; Asch, 1971).

Water was withdrawn by a siphon with plankton netting over the tip and replaced with formalin to make a final concentration of 4%. The method of Haney and Hall (1973) of the addition of 0.12 M sucrose solution to the 4% formalin was used in the preservation method which prevented ballooning and decreased egg loss of the cladocerans. An attempt was made to anesthetize the specimens with charged water before preserving, but the CO_2 caused the cladoceran carapace to open and release the eggs and the method was discontinued.

Upon returning to the laboratory, the contents of each sample was emptied into a gridded petri dish and a sub-sample counted using a 30x B&L stereomicroscope. The

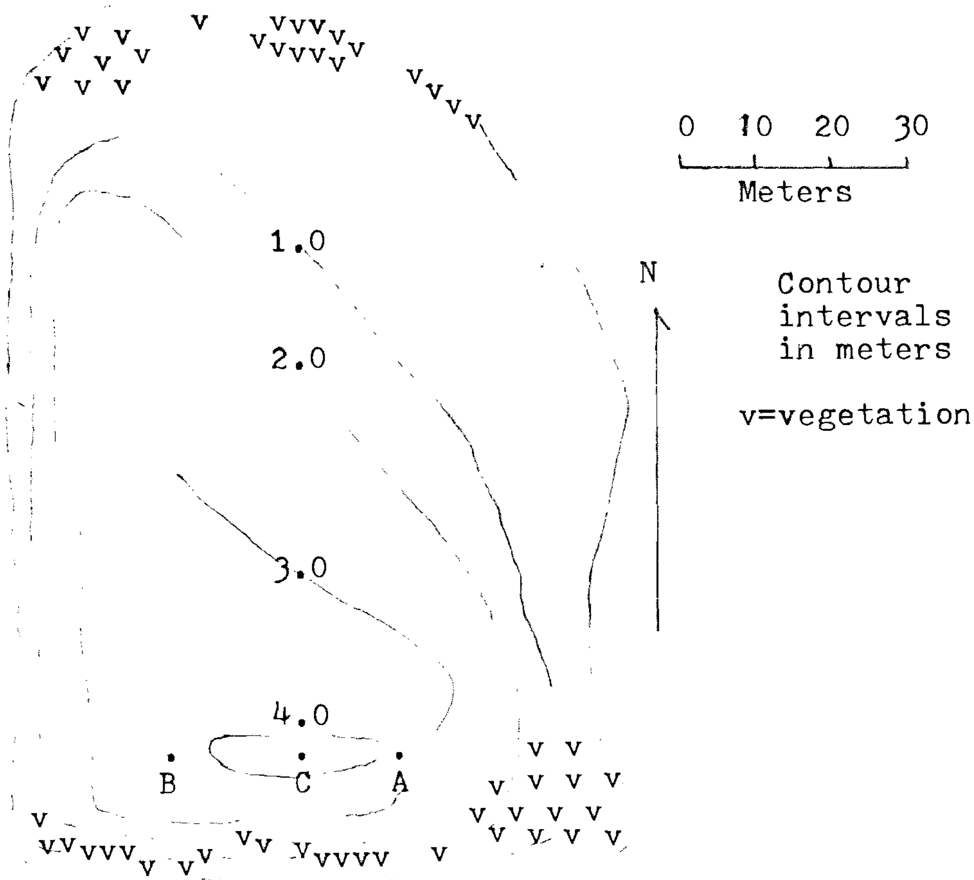

Figure 1. Sampling stations, depth contours, and vegetation of Haglan's Pond.

organisms in the orders Copepoda and Cladocera were identified to species using Edmondson (1963), Pennak (1963), and Brooks (1957). Statistical evaluations were done (Sokal and Rohlf, 1973).

Physical measurements and all water samples taken for chemical analysis were obtained at the four depths at the two end stations. Temperature was measured with a Yellow Springs Instrument Tele-Thermometer with an accuracy of $\pm$ 0.5° C. The amount of light penetration in the visible light range was measured by a submarine photometer, Model No. 268WA300, Kahl Scientific Co. with an underwater and a deck photocell which was then computed into footcandles; secchi disk readings were made with a 20 cm disk; phosphate and nitrate readings were made with a Hach DR-A-4084 Colorimeter and pH was determined with a Bechman Electromate 100900. Alkalinity was determined by the methyl orange indicator method, and carbon dioxide was determined by the titrimetric method for free carbon dioxide as described by Welch (1948). Analysis that were made at the stations included light penetration, light transmission, and temperature. Within an hour after collection pH, alkalinity, and CO_2 were determined. Upon returning to the laboratory, phosphates and nitrates were determined within four hours after collection.

RESULTS

The physical and chemical data collected at the two stations at the four sampling depths has been published in a concurrent study (Ludwig, 1974) along with a discussion of those results.

The microcrustaceans that were identified included three cladocerans, Daphnia parvula Fordyce 1901, Bosmina longirostris (O. F. Muler) 1785, Ceriodaphnia lacustris Birge 1893, and two copepods, Diaptomus pallidus Herrick 1879 and Mesocyclops edax (S. A. Forbes) 1891. Within a period of about two weeks after sampling started, D. parvula died out. C. lacustris was first identified one week after sampling started on June 21. The other species maintained their population numbers through the study.

Figure 2 illustrates the total numbers that were collected for each of the sampling dates. The total numbers represents the mean/1 of the three sampling stations and the four sampling depths. Through the study on various days one station usually had more organisms than the other, however the organisms did not locate at any of the sites more than the others.

Daphnia parvula showed clumping at one station only on one sampling date. On June 19 Station B had 55% (Table 1) of this species which were primarily located at the 2.5 m depth (Table 2). The last date that any D. parvula were collected

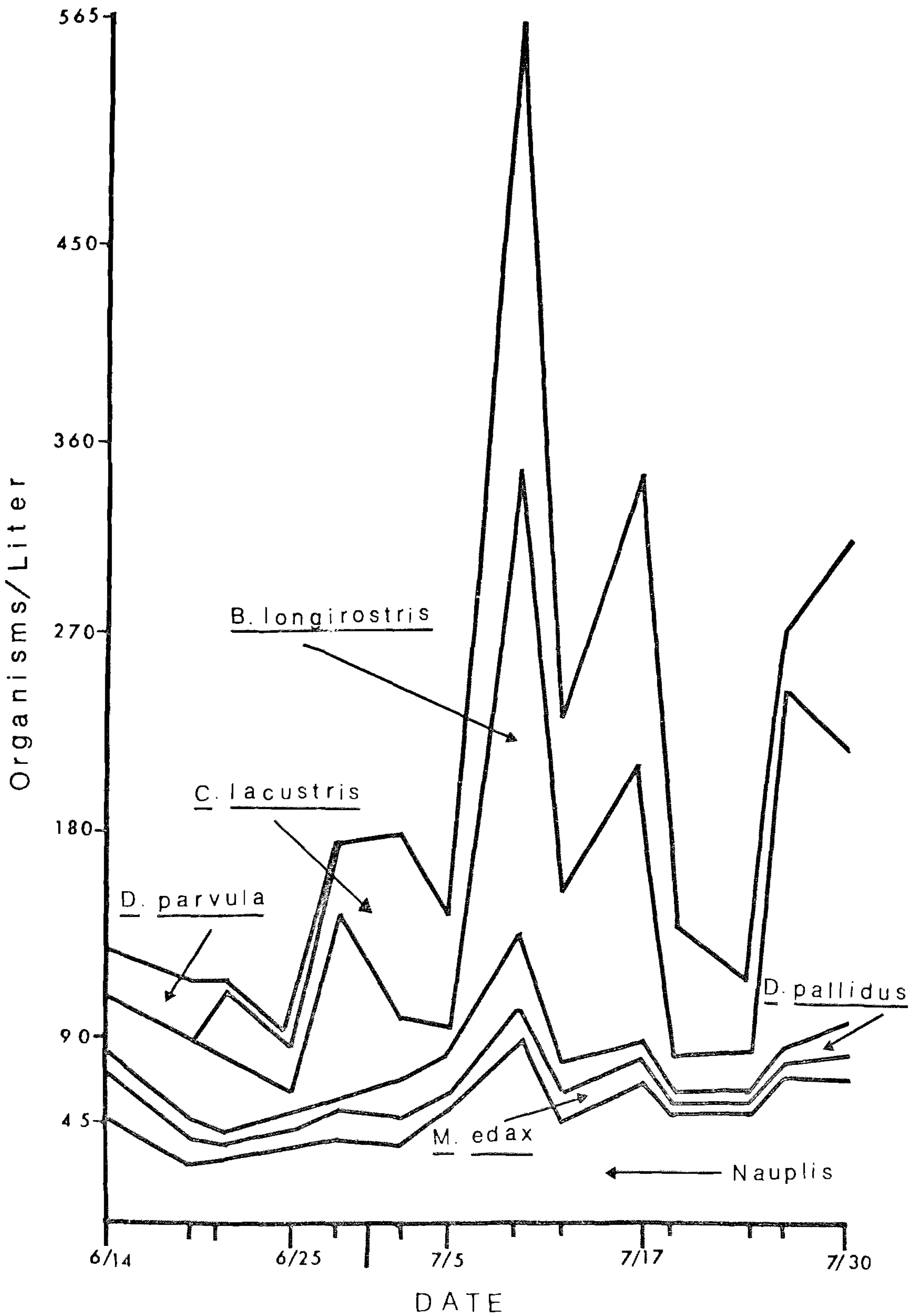

Figure 2. Total population density (#/l) of each species. Summer 1973.

Table 1. Abundance (number/l) by stations, mean, and percent of microcrustaceans for *Daphnia parvula* in an Iowa Farm Pond, Summer 1973.

Date	A	B	C	MEAN	%
6/14	28.8	29.9	-	29.3	23.1
6/19	13.6	53.8	27.6	31.7	34.6
6/21	1.4	3.1	1.3	1.9	1.7
6/25	2.8	4.9	5.8	4.5	5.3
6/28	2.0	2.2	1.2	1.8	1.0
7/2	0.3	0.0	0.0	0.1	0.0
7/5	0.0	0.0	0.0	0.0	0.0

Table 2. Abundance (number/l) of *Daphnia parvula* by depth in an Iowa Farm Pond, Summer 1973. Summary by mean and standard deviation.

	Depth(m)			
Date	0.5	1.5	2.5	3.5
6/14	0.5	21.0	70.7	17.0
6/19	1.6	14.7	80.3	17.5
6/21	1.2	2.3	2.7	1.5
6/25	0.0	0.5	8.3	9.2
6/28	0.0	0.0	5.0	2.2
7/2	0.0	0.0	0.3	0.0
7/5	0.0	0.0	0.0	0.0
$\bar{X} \pm SD$	1.1 $\pm$0.5	9.6 $\pm$9.8	27.9 $\pm$37.1	9.5 $\pm$7.7

was July 2, when only five specimens (0.3/l) were collected at station A at the 2.5 m depth. The last gravid female were collected on June 25 (Table 3), which means that the population remained for approximately one week after the last eggs were produced. The eggs of the gravid females were not the diapause eggs.

Bosmina longirostris, the smallest cladoceran collected, had a peak population density on July 9, which was 216.4/l of which about 60% were located at station C (Table 4) and about 90% were located at the 2.5 m depth (Table 5). Total numbers varied greatly through the study with some increasing as much as 1000% in a week. The percent of gravid females increased to 50.9% on July 2, after which it decreased only to rise again to 35.6% at the end of the study on July 30 (Table 6). None of the observed gravid females ever had more than one egg or embryo in her brood pouch.

Ceriodaphnia lacustris was not identified until the third sampling date, July 21, 1973, a week after sampling started. After this it became an almost equal dominant and dynamic species as *B. longirostris*. *C. lacustris* also reached its highest density (216.6/l) on July 9, when about half were found at station C (Table 7), and about 85% were found at the 2.5 m depth (Table 8). *C. lacustris* did represent from 25 to 40% of the total zooplankton populations on more dates than did *B. longirostris*; however the total

Table 3. Abundance and reproductive condition of *Daphnia parvula* collected in an Iowa Farm Pond, Summer 1973. Units in number/l.

Date	Adults	% Gravid	Total Gravid	Eggs/ Female	Eggs
6/14	29.3	2.6	0.7	1.4	1.0
6/19	31.7	5.1	1.6	1.2	2.0
6/21	1.9	15.0	0.3	1.1	0.2
6/25	4.5	2.3	0.1	1.0	0.1
6/28	1.8	0.0	0.0	0.0	0.0
7/2	0.1	0.0	0.0	0.0	0.0
7/5	0.0	0.0	0.0	0.0	0.0

Table 4. Abundance (number/l) by stations, mean, and percent of microcrustaceans for *Bosmina longirostris* in an Iowa Farm Pond, Summer, 1973.

Date	A	B	C	MEAN	%
6/14	17.4	14.5	-	15.9	12.5
6/19	23.7	17.0	6.7	15.8	17.2
6/21	40.9	37.7	41.2	39.9	35.8
6/25	3.9	6.6	3.3	4.6	5.4
6/28	231.9	12.4	17.9	87.4	47.7
7/2	17.4	61.4	2.4	27.1	15.1
7/5	4.6	20.2	6.8	10.5	7.5
7/9	165.9	92.9	389.5	216.4	38.3
7/12	11.0	94.9	146.2	84.1	35.2
7/17	156.0	123.1	106.7	128.6	37.0
7/19	4.0	40.5	6.2	16.9	12.4
7/24	21.0	6.0	27.5	18.2	16.5
7/26	39.0	357.0	110.0	168.7	60.5
7/30	52.7	128.2	183.0	121.3	37.8

Table 5. Abundance (number/l) of <u>Bosmina</u> <u>longirostris</u> by depth in an Iowa Farm Pond, Summer 1973. Summary by mean and standard deviation.

	Depth(m)			
	0.5	1.5	2.5	3.5
Date				
6/14	0.7	20.1	31.2	9.0
6/19	0.8	9.2	43.0	6.7
6/21	2.2	3.3	144.2	10.1
6/25	0.5	2.7	11.2	4.0
6/28	4.8	3.8	325.0	16.0
7/2	0.3	8.7	90.4	8.8
7/5	0.0	15.0	25.4	1.8
7/9	6.0	42.0	749.7	66.7
7/12	4.7	53.7	224.2	53.7
7/17	11.3	92.3	208.3	202.5
7/19	3.0	3.4	38.7	22.3
7/24	1.7	4.7	36.0	30.3
7/26	26.7	20.7	324.7	302.7
7/30	3.7	25.7	237.7	218.3
$\bar{X} \pm SD$	4.7 $\pm$7.0	21.8 $\pm$25.5	177.8 $\pm$199.2	68.1 $\pm$98.0

Table 6. Abundance and reproductive condition of <u>Bosmina longirostris</u> collected in an Iowa Farm Pond, Summer 1973. Units in number/l.

Date	Adults	% Gravid	Total Gravid	Eggs/ Female	Eggs
6/14	15.9	0.4	0.1	1.0	0.1
6/19	15.8	0.9	0.4	1.0	0.1
6/21	39.9	10.7	4.3	1.0	4.3
6/25	4.6	0.9	0.0	1.0	0.0
6/28	87.4	35.6	31.1	1.0	31.1
7/2	27.1	50.9	13.8	1.0	13.8
7/5	10.5	16.9	1.8	1.0	1.8
7/9	216.4	23.6	51.0	1.0	51.0
7/12	84.1	6.5	5.5	1.0	5.5
7/17	128.6	18.5	23.8	1.0	23.8
7/19	16.9	6.7	1.1	1.0	1.1
7/24	18.2	23.8	4.3	1.0	4.3
7/26	168.7	25.8	43.5	1.0	43.5
7/30	121.3	35.6	43.2	1.0	43.2

Table 7. Abundance (number/l) by stations, mean, and percent of microcrustaceans for *Ceriodaphnia lacustris* in an Iowa Farm Pond, Summer 1973.

Date	A	B	C	MEAN	%
6/14	-	-	-	-	-
6/19	-	-	-	-	-
6/21	18.7	47.9	24.3	30.3	27.2
6/25	26.6	34.6	21.6	27.6	32.5
6/28	71.2	21.4	24.8	39.1	21.3
7/2	33.1	112.9	114.5	86.8	48.1
7/5	44.7	49.5	70.5	54.9	39.4
7/9	121.6	195.7	332.5	216.6	38.3
7/12	16.2	106.5	141.1	88.0	36.9
7/17	78.4	165.9	163.0	135.8	39.1
7/19	53.7	79.5	54.2	62.5	46.6
7/24	27.5	13.2	59.0	31.2	28.3
7/26	12.2	27.0	46.2	28.5	10.2
7/30	30.2	153.5	125.0	102.9	32.0

Table 8. Abundance (number/l) of <u>Ceriodaphnia lacustris</u> by depth in an Iowa Farm Pond, Summer 1973. Summary by mean and standard deviation

	Depth(m)			
	0.5	1.5	2.5	3.5
Date				
6/14	-	-	-	-
6/19	-	-	-	-
6/21	1.8	0.6	101.2	17.5
6/25	0.2	0.3	98.3	11.3
6/28	1.3	0.8	119.2	11.5
7/2	0.8	5.7	360.8	18.0
7/5	1.2	2.8	213.3	6.0
7/9	5.3	85.0	729.2	47.0
7/12	5.7	68.3	229.8	48.0
7/17	2.3	81.3	215.0	61.5
7/19	2.3	6.7	192.0	49.0
7/24	0.3	39.0	66.0	19.7
7/26	0.7	2.7	67.0	43.3
7/30	2.3	8.0	270.3	131.0
$\bar{X} \pm SD$	2.0 $\pm$1.8	26.6 $\pm$36.3	221.8 $\pm$183.1	38.6 $\pm$34.5

numbers did not vary as greatly. Generally less than one percent of the population at 2.5 m was located at the 0.5 m depth. The percent of gravid females increased from 7.2% on July 21 to 35.9% on July 5. Also between those same dates the number of eggs per female increased from 1.2 to 2.4 (Table 9). Following that peak, the number of eggs per female dropped to 1.0 on July 17, and then started to increase slowly to 1.7 on July 30.

The highest population density for Diaptomus pallidus was on July 9, when there were an average of 17.0/l of which about 55% were located at station C (Table 10) and about 85% were found at the 2.5 m depth (Table 11). Eggs per female generally increased from 5.6 on June 14 to 11.4 on July 12 where it remained fairly steady for about two weeks, and then it started to drop (Table 12). The percent of gravid females as compared to the total population fluctuated greatly. The total number of gravid females/l always remained low, 0.5 to 1.7/l.

Mesocyclops edax had its highest population peak on July 9 of 34.9/l of which 40% were located at station C (Table 13) and about 95% were found at the 2.5 m depth (Table 14). On July 9 when the density was the highest, no gravid females were collected (Table 15). When the study started, June 14, 1973, M. edax had its highest number of eggs/gravid female, 30.7; however, the adults/l and percent gravid were low 9.3 and 2.3 respectively. The highest

Table 9. Abundance and reproductive condition of *Ceriodaphnia lacustris* collected in an Iowa Farm Pond, Summer 1973. Units in number/l.

Date	Adults	% Gravid	Total Gravid	Eggs/ Female	Eggs
6/14	-	-	-	-	-
6/19	-	-	-	-	-
6/21	30.3	7.2	2.2	1.2	2.5
6/25	27.6	21.2	5.8	1.3	7.7
6/28	39.1	20.0	7.8	1.2	9.1
7/2	86.8	19.4	16.8	1.7	28.0
7/5	54.9	35.9	19.7	2.4	46.3
7/9	216.0	11.0	23.8	1.4	33.8
7/12	88.0	7.2	6.3	1.1	7.0
7/17	135.8	19.7	26.8	1.0	29.4
7/19	62.5	14.5	9.1	1.1	9.6
7/24	31.3	21.7	6.8	1.2	8.3
7/26	28.5	18.4	5.2	1.3	7.0
7/30	102.9	31.1	32.0	1.7	55.7

Table 10. Abundance (number/l) by stations, mean, and percent of microcrustaceans for <u>Diaptomus pallidus</u> in an Iowa Farm Pond, Summer 1973.

Date	A	B	C	MEAN	%
6/14	22.3	25.3	-	23.8	18.8
6/19	8.3	12.5	11.9	10.9	11.9
6/21	1.9	4.6	8.0	4.8	4.3
6/25	2.7	6.9	9.0	6.2	7.3
6/28	7.4	17.4	5.6	10.3	5.6
7/2	10.3	16.0	6.9	11.1	6.2
7/5	2.8	8.6	3.9	5.1	3.7
7/9	10.9	13.1	27.0	17.0	3.0
7/12	0.2	11.0	11.8	7.7	3.2
7/17	6.7	15.4	8.9	10.3	3.0
7/19	0.5	3.2	4.7	2.8	2.1
7/24	2.0	1.7	5.0	2.9	2.6
7/26	1.0	7.7	7.5	5.4	1.9
7/30	1.2	18.0	17.5	12.2	3.8

Table 11. Abundance (number/l) of <u>Diaptomus pallidus</u> by depth in an Iowa Farm Pond, Summer 1973. Summary by mean and standard deviation.

	Depth(m)			
	0.5	1.5	2.5	3.5
Date				
6/14	0.7	30.6	41.2	19.5
6/19	0.6	2.2	37.8	4.0
6/21	0.3	0.6	16.5	1.8
6/25	1.0	0.3	14.7	8.7
6/28	0.7	0.8	33.3	6.3
7/2	0.3	2.8	40.4	0.7
7/5	1.6	5.7	14.1	3.7
7/9	1.0	3.0	60.0	4.7
7/12	0.0	5.7	20.8	4.3
7/17	0.0	0.0	35.8	5.5
7/19	0.3	1.7	5.0	5.7
7/24	0.7	3.7	6.0	1.3
7/26	0.3	1.3	12.7	7.3
7/30	0.3	2.3	29.3	17.0
$\bar{X} \pm SD$	0.6 $\pm$0.4	4.1 $\pm$7.5	26.3 $\pm$15.9	6.5 $\pm$5.5

Table 12. Abundance and reproductive condition of *Diaptomus pallidus* collected in an Iowa Farm Pond, Summer 1973. Units in number/l.

Date	Adults	% Gravid	Total Gravid	Eggs/ Female	Eggs
6/14	23.8	2.7	0.6	5.6	3.6
6/19	10.9	9.6	1.1	6.0	6.3
6/21	4.8	11.6	0.6	5.2	2.9
6/25	6.2	13.5	0.8	7.2	6.0
6/28	10.3	9.9	1.0	8.7	8.8
7/2	11.1	15.7	1.7	7.3	12.8
7/5	5.1	7.0	0.4	10.3	3.7
7/9	17.0	8.3	1.4	9.3	13.1
7/12	7.7	14.1	1.1	11.4	12.4
7/17	10.3	16.1	1.7	10.4	17.3
7/19	2.8	23.5	0.7	11.4	7.5
7/24	2.9	17.1	0.5	11.3	5.6
7/26	5.4	8.4	0.5	8.6	3.9
7/30	12.2	12.2	1.5	9.0	13.5

Table 13. Abundance (number/l) by station, mean, and percent of microcrustaceans, for <u>Mesocyclops edax</u> in an Iowa Farm Pond, Summer 1973.

Date	A	B	C	MEAN	%
6/14	12.9	5.7	-	9.3	7.3
6/19	8.6	4.5	11.1	8.1	8.8
6/21	3.6	4.6	4.6	4.3	3.9
6/25	6.9	6.2	13.9	9.0	10.6
6/28	2.6	7.4	2.5	4.2	2.3
7/2	27.8	26.1	7.8	20.6	11.4
7/5	13.4	17.2	16.8	15.8	11.3
7/9	18.1	27.1	59.5	34.9	6.1
7/12	1.5	14.0	7.6	7.7	3.2
7/17	7.0	10.9	5.5	7.8	2.2
7/19	2.0	4.5	4.7	3.7	2.7
7/24	5.7	3.2	5.2	4.7	4.3
7/26	2.2	7.0	6.5	5.2	1.9
7/30	5.0	21.2	19.0	15.1	4.7

Table 14. Abundance (number/l) of Mesocyclops edax by depth in an Iowa Farm Pond, Summer 1973. Summary by mean and standard deviation.

	Depth(m)			
	0.5	1.5	2.5	3.5
Date				
6/14	0.0	3.7	20.5	17.5
6/19	0.1	0.4	21.8	12.0
6/21	0.5	0.3	5.7	10.5
6/25	1.0	1.2	10.4	14.3
6/28	2.0	0.8	4.6	9.3
7/2	1.0	5.3	70.8	5.2
7/5	0.0	4.5	56.2	2.5
7/9	0.0	1.7	130.0	6.3
7/12	0.3	2.3	23.8	5.0
7/17	0.0	1.3	11.7	14.8
7/19	0.7	1.0	12.3	4.3
7/24	0.0	3.0	4.3	11.7
7/26	0.3	0.3	8.0	12.3
7/30	0.3	2.0	21.0	37.0
$\bar{X} \pm SD$	0.5 $\pm$0.6	2.0 $\pm$1.6	28.7 $\pm$35.1	11.6 $\pm$8.6

Table 15. Abundance and reproductive condition of *Mesocyclops edax* collected in an Iowa Farm Pond, Summer 1973. Units in number/l.

Date	Adults	% Gravid	Total Gravid	Eggs/ Female	Eggs
6/14	9.3	2.3	0.2	30.7	6.6
6/19	8.1	3.8	0.3	24.9	7.7
6/21	4.3	10.8	0.5	23.8	11.1
6/25	9.0	9.3	0.8	20.4	17.1
6/28	4.2	26.9	1.1	21.0	23.7
7/2	20.6	4.0	0.8	21.6	17.8
7/5	15.8	12.6	2.0	23.5	46.8
7/9	34.9	0.0	0.0	0.0	0.0
7/12	7.7	8.1	0.6	20.0	12.5
7/17	7.8	9.0	0.7	25.3	17.8
7/19	3.7	2.2	0.1	28.0	2.8
7/24	4.7	1.8	0.1	18.0	1.8
7/26	5.2	0.0	0.0	0.0	0.0
7/30	15.1	1.7	0.3	28.0	7.2

number of gravid females/l and eggs/l occurred on July 5 when two gravid females/l produced almost 47 eggs/l (Table 15).

The copepod population paralleled the nauplius numbers through the study (Figure 2). The nauplii generally represented about two to four times or more, the number of D. pallidus or M. edax. The nauplii were not identified to species or to instars. The total numbers of nauplii varied; but when compared to the copepod population they resembled an almost stable population. Only on two sampling dates did one station contain 50% of the larva collected (Table 16); otherwise the population was fairly evenly distributed between the stations.

As indicated by Tables 1, 4, 7, 10, 13, 16 none of the three stations consistently had more organisms/l than the others. It was anticipated that with three stations the average number/l would not peak or dip as violently as with one or two stations; however these tables indicate that the fluctuations were still present. These tables also present the mean which is the average of 12 samples per date and a percent which represents the contribution of a particular species population to the total number of organisms collected for a particular date.

Tables 2, 5, 8, 11, 14, 17 illustrate a comparison of the various species number/l for each of the four sampling depths. The 2.5 m depth consistently had more organisms than any other depth; while the 0.5 m depth consistently had

Table 16. Abundance (number/l) by stations, mean, and percent of microcrustaceans, for the nauplius in an Iowa Farm Pond, Summer 1973.

Date	A	B	C	MEAN	%
6/14	71.3	25.9	-	48.6	38.3
6/19	24.2	25.5	26.0	25.2	17.5
6/21	27.6	33.1	30.4	30.4	27.2
6/25	38.2	30.7	30.0	33.0	38.9
6/28	42.7	33.1	45.5	40.4	22.1
7/2	31.6	51.5	20.6	34.6	19.2
7/5	50.8	68.2	40.9	53.3	38.1
7/9	80.7	63.6	99.0	81.1	14.2
7/12	32.5	54.0	67.7	51.4	21.5
7/17	73.2	57.0	65.1	65.1	18.7
7/19	45.5	60.2	42.5	49.4	36.2
7/24	51.7	51.2	57.0	53.3	48.3
7/26	48.2	101.0	64.2	71.2	25.5
7/30	41.7	97.7	69.7	69.7	21.7

Table 17. Abundance (number/l) of nauplius by depth in an Iowa Farm Pond, Summer 1973. Summary by mean and standard deviation.

	Depth(m)			
	0.5	1.5	2.5	3.5
Date				
6/14	36.0	47.7	45.5	107.0
6/19	32.2	31.3	21.0	12.0
6/21	30.5	35.6	35.2	19.0
6/25	23.3	46.2	48.6	13.8
6/28	51.6	45.8	59.6	4.7
7/2	12.3	41.4	68.7	15.8
7/5	23.8	58.3	124.6	5.5
7/9	17.3	38.7	250.8	17.7
7/12	33.3	46.6	92.3	33.3
7/17	31.3	65.0	142.5	28.3
7/19	48.0	53.3	72.3	24.0
7/24	20.7	51.3	111.7	29.7
7/26	54.0	56.7	96.7	77.3
7/30	41.7	46.3	133.3	57.7
$\bar{X} \pm SD$	32.6 $\pm$12.7	47.4 $\pm$9.1	93.1 $\pm$59.0	31.5 $\pm$29.6

fewer adult organisms.

Table 18 is a comparison of data collected on July 24 and July 26, 1973 using the Student t Test. Three sets of data were collected on those dates: (1) the regular three station samples A, B, and C at 1.5 m, (2) ten samples collected at 1.5 m at station A, and (3) ten samples collected at 1.5 m while rowing a boat in water deeper than 3.0 m in close proximity to the three stations. The data that was collected on each species was compared to the other two sets collected on that particular date by using the t Test. On July 24, there were six very significant (.99) results, three significant (.95) results, and six nonsignificant results. On July 26, and identical set of data was collected and the results were different with only five very significant, one significant, and nine nonsignificant results (Table 18). The t values obtained on the population data of July 24 indicates that the species were more non-randomly distributed than on July 26. The more nonsignificant t values, obtained on the July 26 date, indicate that the species were more randomly distributed rather than occurring in clumps as on July 24.

The cladoceran populations fluctuated greatly throughout the study (Figure 2). The t Test indicated that the cladocerans were collected in highly populated zones with several very significant results from the July 24 and July 26 data. The distribution of the adult copepods was not as

Table 18. A comparison of data collected on July 24 and July 26 from an Iowa Farm Pond, Summer 1973 using the Student t Test.

Station A

Random Row	B. l.	C. l.	D. p.	M. e.	N.
B. l.					
7/24	**				
7/26	**				
C. l.					
7/24		**			
7/26		**			
D. p.					
7/24			**		
7/26			NS		
M. e.					
7/24				*	
7/26				NS	
N.					
7/24					NS
7/26					NS

Station A

Regular 3 Station Sample	B. l.	C. l.	D. p.	M. e.	N.
B. l.					
7/24	*				
7/26	**				
C. l.					
7/24		NS			
7/26		**			
D. p.					
7/24			NS		
7/26			*		
M. e.					
7/24				NS	
7/26				NS	
N.					
7/24					NS
7/26					NS

Table 18 continued.

Regular 3 Station Sample

Random Row	B. l.	C. l.	D. p.	M. e.	N.
B. l.					
7/24	**				
7/26	NS				
C. l.					
7/24		**			
7/26		NS			
D. p.					
7/24			**		
7/26			NS		
M. e.					
7/24				*	
7/26				NS	
N.					
7/24					NS
7/26					NS

NS nonsignificant
* significant
** very significant

clumped as the cladocerans as indicated by the several nonsignificant and significant results in the t Test in Table 18. The nauplii were distributed randomly on both dates as indicated by the nonsignificant values obtained by the t Test.

DISCUSSION

Early limnologists, studying zooplankton, attempted to identify when populations of organisms reached their maximum numbers, and when they declined as well as attempting to identify environmental factors responsible for the fluctuations found in the microcrustacea populations. More recent research has concentrated on the determination of birth rate, death rate, and the natural rate of increase. During the current study no environmental factor varied greatly, and this may explain why none seemed to be influencing the population size. Sampling occurred during mid-summer when temperature and available light were at a rather stable maximum level.

A concurrent study on the pond by Ludwig (1974) described the environmental factors occurring during the sampling period. A visual comparison of data obtained by Ludwig (1974) illustrates that there was no apparent interdependence between the occurrence of maximum population densities with air temperature, sky conditions, water temperature and mineral concentration. However, it was found that light controlled vertical distribution of the population in the pond. The maximum concentrations of zooplankton were located at the 2.5 m depth where the mean light penetrance was 5.0% of the amount of light reaching the surface. Biological factors such as predation and competition are probably important, but there was no method of measuring these factors incorporated into this study.

The species composition of this farm pond was similar to the typical limnetic grouping established by Pennak (1957). The five species identified, *D. parvula*, *B. longirostris*, *C. lacustris*, *D. pallidus*, and *M. edax* are common microcrustaceans to the mid-western states (Edmondson, 1963; Pennak, 1963; Brooks, 1957). In a study of six northeastern Kansas lakes Armitage (1961) found that four or five of these same species usually occurred together. He also found that *D. parvula*, *B. longirostris*, and *D. pallidus* are perennial, *C. lacustris* is probably autumnal and *M. edax* occurs from late spring through fall. Other mid-western lakes, ponds, and reservoirs yielded some of the same species (McGrath, 1973; Asch, 1971; Bulkley and Scheider, 1970; Cowell, 1967).

In any project that involves sampling natural populations, the problem of sampling error becomes important. In order to determine the amount of error in sampling, the coefficient of variation can be calculated by the formula:

$$V = \frac{s}{\bar{X} \cdot 100}$$

with s being the standard deviation and $\bar{X}$ being the mean (Sokal and Rohlf, 1973). The coefficient of variation calculated was based on the total number of organisms collected at the three stations on a given date with the larger value representing the greater variation. The mean coefficient of variation of the total counts for the entire study was 45%.

On both July 24 and July 26, 1973, ten duplicate samples were collected at Station A and ten random row samples were collected in close proximity to the three stations at the 1.5 m depth. Large variations were found between samples and between dates (Table 19).

This illustrates that the zooplankton population showed non-random or superdispersion distributions which is consistent with the idea expressed by Hutchinson (1967) that superdispersion exists in plankton populations. Both McGrath (1973) and Asch (1971) found evidence of superdispersion of zooplankton in Red Rock Reservoir, Iowa.

A convenient way of expressing reproductive intensities when egg ratios are known can be calculated (George and Edwards, 1974; Edmondson, 1968; Wright, 1965; Hall, 1964). If the number of eggs in a population (E) is known, and the duration of development of the eggs (D) determined, then given the initial population size (N_0), the finite birth rate or number of newborn per individual per day (B) may

Table 19. Coefficient of variation (%) of the regular three station samples, 10 station A samples, and 10 random row samples taken from the 1.5 meter depth on July 24 and July 26 by species. Iowa Farm Pond, Summer 1973.

	Regular Three Stations	Station A	Random Row
B. longirostris			
7/24	101	66	79
7/26	30	96	66
C. lacustris			
7/24	124	55	86
7/26	68	106	119
D. pallidus			
7/24	56	47	136
7/26	87	210	106
M. edax			
7/24	120	115	130
7/26	-	176	210
Total Numbers			
7/24	100	71	108
7/26	46	147	125

be calculated as follows (George and Edwards, 1974):

$$B = \frac{E}{(D)(N_o)}$$

If B is determined, an estimate of the natural birth rate (b') may be calculated:

$$b' = \log_e (1 + B)$$

although this holds rigorously for a population with a stable age distribution it can be applied to a non-steady-state population as an approximation.

A measure of the actual or net rate of population growth, the coefficient of population growth (r'), can be calculated from successive pairs of population density values. If N_o is the initial population and N_t is the population after time t, then on the basis of the natural growth equation:

$$N_t = N_o e^{rt}$$

and

$$r' = \frac{\log_e N_t - \log_e N_o}{t}$$

knowing b' and r' a mortality rate (d') may be calculated since

$$d' = b' - r'$$

The prime sign will be used to show that the population parameters have been calculated from estimates of plankton numbers rather than from age-specific natality and mortality.

Many of the researchers calculating population dynamics were using a controlled environment (Geiling and Campbell, 1972; Hall et al., 1970; Hall, 1964; Hazelwood and Parker, 1961; Frank et al., 1957; Slobodkin, 1954).

Ludwig (1974) determined that primary productivity reached two major peaks in the study period, July 2 (575 mg $C/m^2/hr$) and July 24 (645 mg $C/m^2/hr$). The zooplankton had the greatest density (565/l on July 9, and a second peak (321/l) on July 30, when the study ended, but the density was still increasing.

None of the environmental factors changed dramatically during these times; so it is assumed that production was primarily responsible for these increases. There was a lag period of about a week between peak production and peak density which seems to correspond to the data that Armitage et al. (1973) and Angino et al. (1973) obtained. All species present did increase on July 9 and July 30, however the greatest increase came from the two cladoceran species. On July 9 the largest portion of zooplankton (75%) were cladocerans which can react more quickly than can copepods to an increased food supply.

Daphnia parvula became extinct three weeks after sampling started and did not reappear in the sampling area of the pond. The first week *D. parvula* maintained a steady concentration, but on June 21 the death rate was extremely high (1.4469) and the birth rate did not compensate (Table 20). The birth rate gradually diminished to zero and the species became extinct. Generally during the period from 6/14 to 7/5 the values obtained for natural rate of increase were negative; the one positive value (6/25) was probably due to error in estimating due to the extremely small population size. The extinction of this species appears to be due to increased mortality and decreased natality.

Other workers have obtained similar densities and egg production rates on various *Daphnia* species (Angino et al., 1973; Dodson, 1973; Elbourn, 1966). Hall (1964) studying the effects of different concentrations of food on *Daphnia galeata mendotae* did make calculations of b', d', and r'. His ponds that received medium amounts of nutrients produced rates which were similar to the data in this study. Dodson (1973) estimated that 93% of all mortality of *Daphnia rosea* was due to predation by *Chaoborus* and *Ambystoma* larva while only 7% was natural mortality. Because the abiotic factors did not change much, it is felt that the main cause of mortality in *D. parvula* in this study was predation.

Bosmina longirostris, a small cladoceran, did respond quickly to the two productivity peaks of 7/2 and 7/24 by showing an elevated birth rate after a lag period of less than a week. Other than this tendency no other conclusion

Table 20. Mean/l, Eggs/l, time between sampling dates, natural growth rate (r'), birth rate (b'), and death rate (d') of <u>Daphnia parvula</u>. Iowa Farm Pond, Summer 1973.

Date	#/l	E/l	t	r	b'	d'
6/14	29.3	1.0	-	-	-	-
6/19	31.7	2.0	5	0.0157	0.0243	0.0085
6/21	1.9	0.2	2	-1.4072	0.0397	1.4469
6/25	4.5	0.1	4	0.2156	0.0085	-0.2071
6/28	1.8	0.0	3	-0.2291	0.0000	0.0229
7/2	0.1	0.0	5	-0.3436	0.0000	0.3436
7/5	0.0	0.0	3	-1.5350	0.0000	1.5350

can be drawn about this species (Table 21).

All of the gravid females that were observed contained only one egg or embryo in a brood pouch. Armitage and Davis (1967) observed the mean number of eggs/gravid female of *B. longirostris* to be 2.4 eggs/female. However the density in their study was not any more stable, nor did it fluctuate to any greater extent than did it in this study. Thus, it is concluded that this species varies greatly as a result of some unknown factor upon its birth and death rates. No previous population dynamics have been worked out for the *Bosmina* genus, therefore it is difficult to determine whether these figures are reasonable of a natural population.

Ceriodaphnia lacustris, a cladoceran approximately the same size as *D. parvula* did not appear in the samples until 6/21. From then on it fluctuated almost as greatly as did *B. longirostris*. It reacted to the peaks in productivity in about the same manner as did *B. longirostris*. On 7/5 the average gravid female produced 2.4 eggs which could account for the high density on 7/9 along with the decreased mortality rate (Table 22).

No dynamic studies have been conducted using the *Ceriodaphnia* species; however since *C. lacustris* is about the same size as *D. parvula* one can assume that the basic requirements are close. Researchers have found that filtering rates and particle size are directly proportional to body size (Confer, 1971; McQueen, 1969; Burns, 1969, 1968; Burns

Table 21. Mean/l, Eggs/l, time between sampling dates, natural growth rate (r'), birth rate (b'), and death rate (d') of Bosmina longirostris, Iowa Farm Pond, Summer 1973.

Date	#/l	E/l	t	r	b'	d'
6/14	15.1	0.1	-	-	-	-
6/19	15.8	0.1	5	-0.0013	0.0024	0.0037
6/21	39.9	4.3	2	0.4632	0.0957	-0.3675
6/25	4.6	0.0	4	-0.5401	0.0000	0.5401
6/28	87.4	31.1	3	0.9815	1.2809	0.2278
7/2	27.1	13.8	5	-0.2343	0.0608	0.2951
7/5	10.5	1.8	3	-0.3161	0.1869	0.5030
7/9	216.4	51.0	4	0.7564	0.7793	0.0229
7/12	84.1	5.5	3	-0.3150	0.0097	0.3247
7/17	128.6	23.8	5	0.0849	0.1033	0.0184
7/19	16.9	1.1	2	-1.0147	0.0688	1.0835
7/24	18.2	4.3	5	0.0148	0.0097	-0.0051
7/26	168.3	43.5	2	1.1122	0.6522	-0.4600
7/30	121.3	43.2	4	-0.0818	0.0941	0.1759

Table 22. Mean/l, Eggs/l, time between sampling dates, natural growth rate (r'), birth rate (b'), and death rate (d') of Ceriodaphnia lacustris, Iowa Farm Pond, Summer 1973.

Date	#/l	E/l	t	r	b'	d'
6/14	-	-	-	-	-	-
6/19	-	-	-	-	-	-
6/21	30.3	2.5	2	-	-	-
6/25	27.6	7.7	4	-0.0233	0.0932	0.1165
6/28	39.1	9.1	3	0.1222	0.1193	-0.0029
7/2	86.8	28.0	5	0.1595	0.2432	0.0837
7/5	54.9	46.3	3	-0.1527	0.1866	0.3393
7/9	216.6	33.8	4	0.3432	0.2126	-0.1306
7/12	88.0	7.0	3	-0.3003	0.0240	0.3243
7/17	135.8	29.4	5	0.0868	0.1185	0.0317
7/19	62.5	9.6	2	-0.3880	0.0268	0.4148
7/24	31.3	8.3	5	-0.1383	0.0498	0.1881
7/26	28.5	7.0	2	0.0469	0.0825	0.0256
7/30	102.9	55.7	4	0.3210	0.5653	0.2443

and Rigler, 1967). The values for b', d' and r' found in the current study for _C. lacustris_ are different than that reported for _Daphnia_ spp., but the differences are not great.

Diaptomus pallidus was the only herbivorous copepod identified. Because of the longer time of development the copepods cannot increase total number as quickly as the cladocerans, nor do they decrease as quickly either. However, a noticeable difference in egg production did occur (Table 12). The mean number of eggs/female gradually increased until it reached a peak (11.1/female) on 7/19. This increase results in a lag period of about three weeks. The birth rate (b') reached a peak on 7/9 and 7/30, which is about a week behind the productivity peak (Table 23). The density change was proportional to the changes in the rate of natural increase. As r' varied so did the population density which would probably be controlled by the death rate since the birth rate did not vary greatly. Angino et al. (1973) calculated similar data for _Diaptomus pallidus_ which was slightly higher. Their research ponds were much shallower which would tend to have a higher temperature giving an elevated reproductive behavior. Hazelwood and Parker (1961) found that _Diaptomus leptomus_ became extinct through the summer months in Washington.

Mesocyclops edax, the largest microcrustacean, was the only predator one found in the pond. It responded to the productivity peaks by increasing egg production to

Table 23. Mean/l, Eggs/l, time between sampling dates, natural growth rate (r'), birth rate (b'), and death rate (d') of _Diaptomus pallidus_. Iowa Farm Pond, Summer 1973.

Date	#/l	E/l	t	r	b'	d'
6/14	23.8	3.6	-	-	-	-
6/19	10.9	6.3	5	-0.1562	0.0116	0.1678
6/21	4.8	2.9	2	-0.4101	0.0118	0.4219
6/25	6.2	6.0	4	0.0640	0.0538	-0.0102
6/28	10.3	8.8	3	0.1692	0.0609	-0.1083
7/2	11.1	12.8	5	0.0149	0.0535	0.0386
7/5	5.1	3.7	3	-0.2592	0.0464	0.3056
7/9	17.0	13.1	4	0.3010	0.1076	-0.1934
7/12	7.7	12.4	3	-0.2640	0.0318	0.2958
7/17	10.3	17.3	5	0.0582	0.0948	0.0366
7/19	2.8	7.5	2	-0.6513	0.0317	-0.6196
7/24	2.9	5.6	5	0.0070	0.0848	0.0778
7/26	5.4	3.9	2	0.3109	0.0578	-0.2531
7/30	12.2	13.5	4	0.2038	0.1049	-0.0989

28/female on 7/19 (Table 15). It showed a slightly longer lag period than D. pallidus. The mean birth rate (0.0496) is slightly lower (Table 24) than that of D. pallidus (0.0578). This indicated that generally it is the lowest density species, and that it will respond to environmental changes the slowest. Population density was directly correlated to the death rate. Although no previous work has been done on Mesocyclops, some data has been collected on some cyclopoids. McQueen (1969) found that Cyclops bicuspidatus thomasi in British Columbia to have a lower density during the summer, but Stross and Kangas (1969) found Cyclops spp. to be much higher in Artic pools than the current study.

Five species of microcrustaceans were identified and followed for the months of June and July with physiochemical parameters being determined. Birth rates, death rates and rate of natural increase were calculated for the species. One species (Daphnia parvula) became extinct during the study and one species (Ceriodaphnia lacustris) was not present when the study started. All species showed noticeable tendencies towards increasing population sizes as productivity increased.

It would be necessary to conduct a long term study of the same pond so a complete understanding could be obtained of development, growth, and extinction of the various populations. It would then be possible to compare this phenomena

Table 24. Mean/l, Eggs/l, time between sampling dates, natural growth rate (r'), birth rate (b'), and death rate (d') of <u>Mesocyclops edax</u>. Iowa Farm Pond, Summer 1973.

Date	#/l	E/l	t	r	b'	d'
6/14	9.3	6.6	-	-	-	-
6/19	8.1	7.7	5	-0.0276	0.0272	0.0548
6/21	4.3	11.1	2	-0.3167	0.0447	0.3614
6/25	9.0	17.1	4	0.1847	0.1245	-0.0602
6/28	4.2	23.7	3	-0.2540	0.0841	0.3381
7/2	20.6	17.8	5	0.3180	0.1321	-0.1859
7/5	15.8	46.8	3	-0.0884	0.0730	0.1614
7/9	34.9	0.0	4	0.1981	0.0000	-0.1981
7/12	7.7	12.5	3	-0.5038	0.0119	0.5157
7/17	7.8	17.8	5	0.0026	0.0742	0.0716
7/19	3.7	2.8	2	-0.3729	0.0119	0.3848
7/24	4.7	1.8	5	0.0479	0.0161	-0.0318
7/26	5.2	0.0	2	0.0506	0.0000	-0.0506
7/30	15.1	7.2	4	0.2665	0.0451	-0.2214

in a variety of other habitats. For a study involving cladocerans an intensive study of one species should be conducted for a period of a few weeks with collections daily. Because of the rapidity of population increases of cladocerans, a two to four day interval between collections misses some fluctuations. For a complete understanding of the zooplankton community, techniques involving evaluations of competition, predation and interactions between populations should be developed and included. The effects of man need to be evaluated on pond population dynamics as well as on the pond ecosystem.

SUMMARY

1. Secondary production of zooplankton was determined in an artificial Iowa farm pond from June 14 to July 30, 1973.

2. Chemical and physical factors were measured for each of four depths at two deep water stations.

3. *Daphnia parvula*, *Bosmina longirostris*, *Ceriodaphnia lacustris*, *Diaptomus pallidus*, and *Mesocyclops edax* were identified.

4. *Daphnia parvula* became extinct and did not reappear.

5. The largest aggregation of zooplankters existed at the 2.5 meter depth.

6. The five zooplankton species were distributed non-randomly throughout the pond.

7. Relationships of abiotic environment to population densities were not apparent during the study.

8. Birth rates, death rates, and the rate of natural increase were determined for the individual species.

9. Food or primary productivity produced the most noticeable population changes.

10. Cladocerans lagged about one week and copepods lagged about two to three weeks behind primary productivity.

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